

FROM  
WHERE THEY LOOK  
TO  
WHAT THEY THINK:  
DETERMINING CONTROLLER COGNITIVE STRATEGIES  
FROM  
OCULOMETER SCANNING DATA

by

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My work this summer has been a real team effort, with initial impetus from Hugh Bergeron of FltMD/VORB and a lot of assistance from fellow ASEE Fellow Herb Armstrong. My task has been to determine what might be learned about the behavior and cognition of air traffic controllers from oculometer scanning data that had already been obtained for another purpose. There has been very little work done to develop models of air traffic controllers, much of what has been done having been done here at Langley. One aim of developing such models is to use them as the basis of decision-support or expert-systems tools to assist controllers in their tasks. Such tools are more likely to be effective if they incorporate the strategies that controllers actually use, rather than steering them in what might be felt to be unnatural directions.

One simple model of controller activity is that of Carlson and Rhodes (Figure 1), in which some of the basic steps of detecting and resolving aircraft conflicts are spelled out in their natural sequence. A more detailed model has been developed by Lohr (Figure 2). Harris and Bonadies have derived some nice quantitative results specifically from scanning data (Figure 3), and Roske-Hofstrand has made some initial efforts toward basing a model on such data (Figure 4). My own impressions as to controller strategy, based on viewing videotapes of the simulation sessions in which the oculometer data were obtained are summarized in an internal report.

In summary, I suggest the following initial hypotheses as to controller strategy:

(1) Controllers formulate and modify their plans in terms of *clusters* of aircraft, rather than *individual* aircraft.

(2) Controllers cluster aircraft based on *closeness in an abstract cognitive space*, rather than simple *separation in physical space*.

(3) Controllers segment their work temporally and dynamically into (*sometimes overlapping*) *episodes* and *subepisodes* defined in terms of the interactions of aircraft clusters.

(4) Controllers *prioritize* the subtasks within their episodes, with different strategies for different subtasks.

(5) Controllers change plans *consequent upon* changes in perceived clustering: *deliberate* cognitive acts are triggered by *presented* changes in conceptualization.

Hypotheses (1)-(3) are illustrated in the report. As an example of hypothesis (4), a controller checks that separation of aircraft is adequate both before and after doing an artificial "side-task" consisting of reading extraneous information about the weather or the like, but he is less thorough in checking before scanning to accept a flashing hand-off aircraft, thereby suggesting that he considers the latter task more important and in need of more immediate attention when it arises. Hypothesis (5) has implications for tool development, in that it suggests limits on the extent to which automated aids should be allowed to deviate from actual controller practice.

In consequence, I suggest the following directions for further investigation:

(1) Determine the *geometry* of the controller's *cognitive space*, i.e., its *dimensions* and *topology* and the *metric* that is used to measure "*closeness*" (i.e., *relevant relatedness*) in that space, *as distinct from separation in physical space*. For example, are clusters determined solely by arrival sequence or do other factors also play a role?

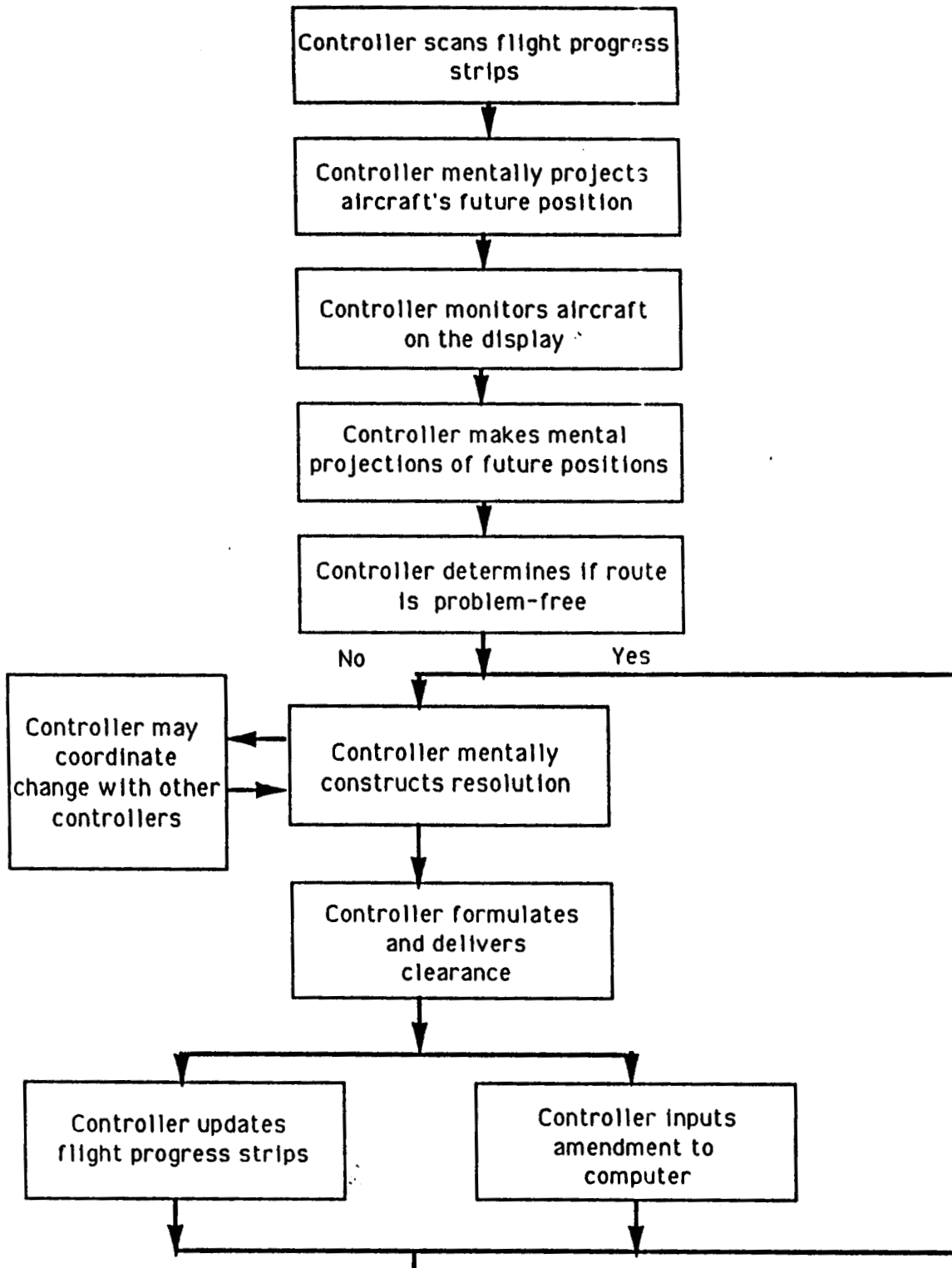
(2) Determine the *metric* that is used to *prioritize* subtasks and the extent of *look-ahead* that is used for *planning* those subtasks. For example, does the controller check aircraft separation *in preparation* for doing the "side-task," or does he do the "side-task" *after having checked* separation?

(3) Determine the range of episode *types* and the extent of episode *nesting* and *overlap*. For example, to what extent does the controller maintain separation *of clusters*, and to what extent is he willing to *shuffle* (i.e., modify and mix) them?

(4) Determine the relative extent and cognitive significance of *intra-* and *inter-*cluster scanning. For example, how often and why does the controller scan *back* to aircraft that are *already* lined up on the localizer, while focusing primarily on a *later* cluster; how often and why does he scan to *outliers* beginning a *new* cluster, while focusing primarily on an *earlier* one?

I hope to help substantially with further investigations of these questions.

**SAMPLE CONTROLLER ACTIVITIES FOR DETECTING AIRCRAFT  
CONFLICTS WITH TODAY'S TECHNOLOGY**



**Figure 1: The Carlson/Rhoades model.**

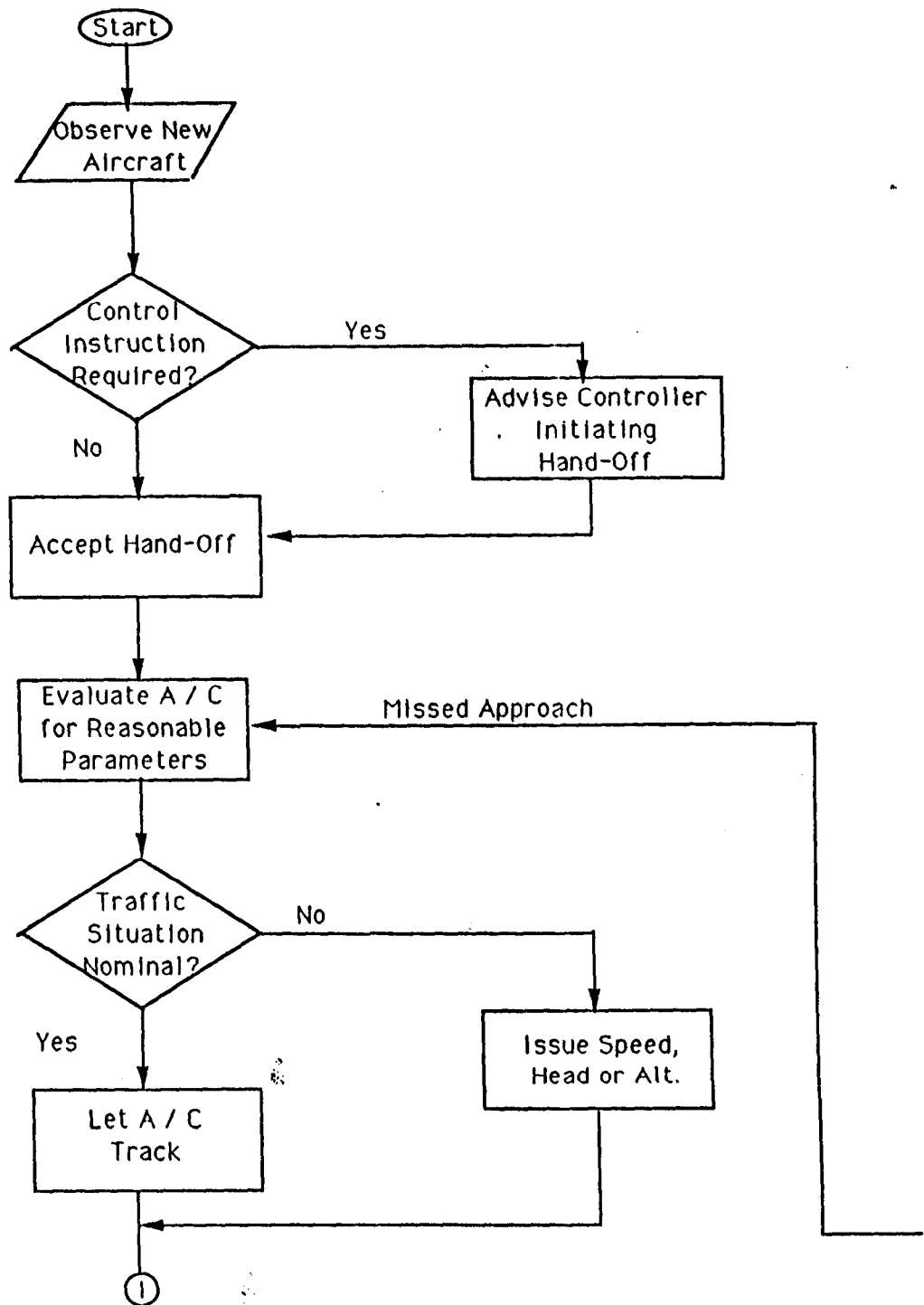


Figure 2: The Lohr model.

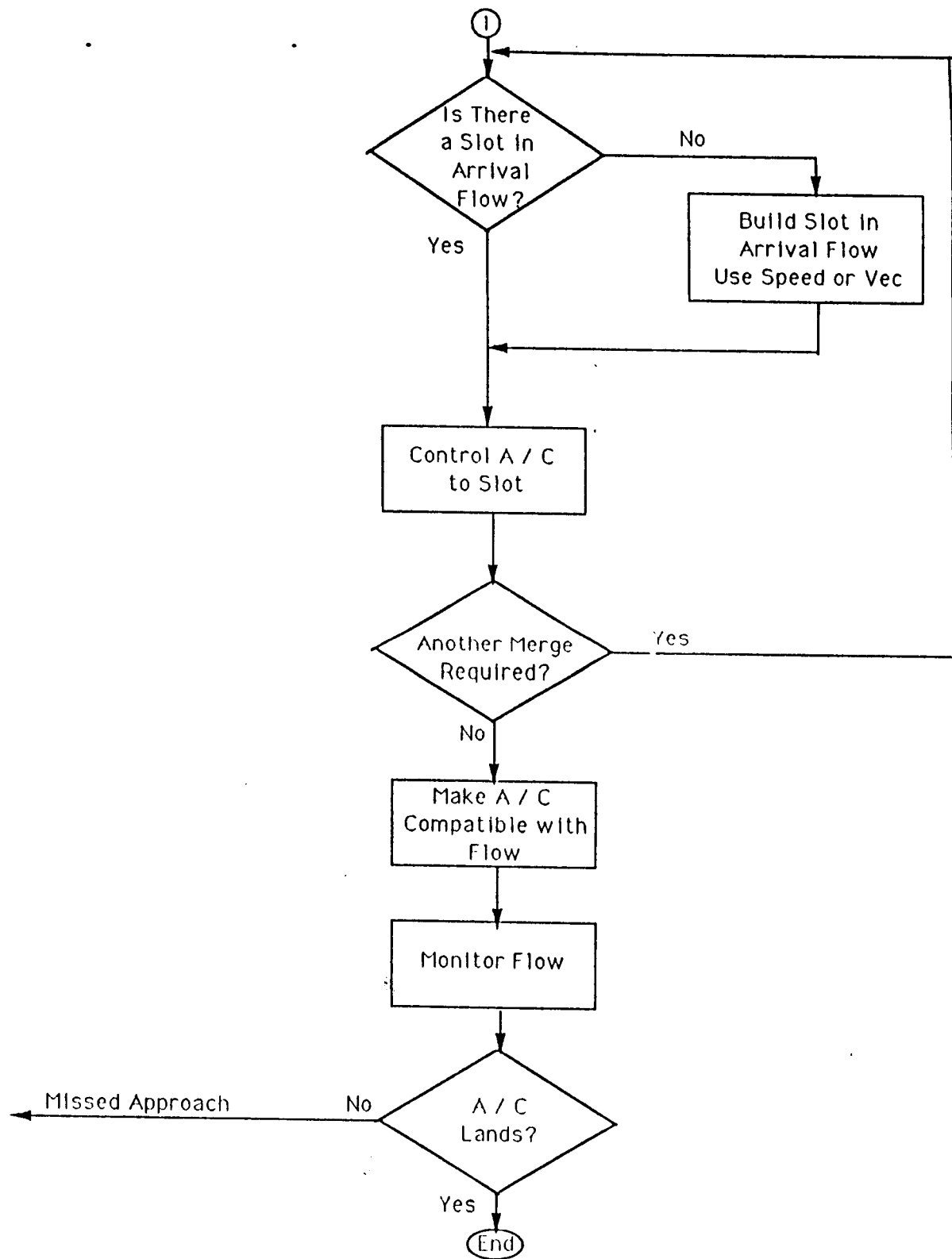
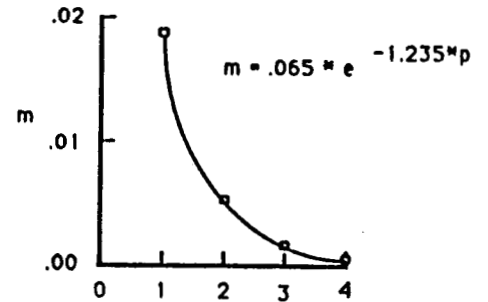
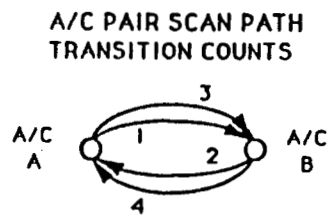
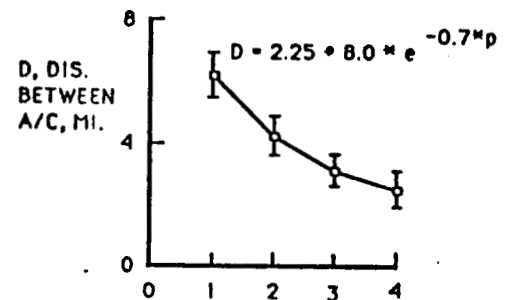


Figure 2 (cont.): The Lohr model.

# MODEL OF CONTROLLER CROSS-CHECK SCANS OF TRAFFIC

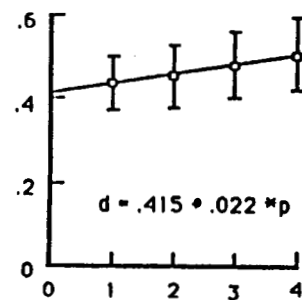


p, A/C PAIR SCAN PATH  
TRANSITION COUNTS



p, A/C PAIR SCAN PATH  
TRANSITION COUNTS

d, DWELL  
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A/C, SEC



p, A/C PAIR SCAN PATH  
TRANSITION COUNTS

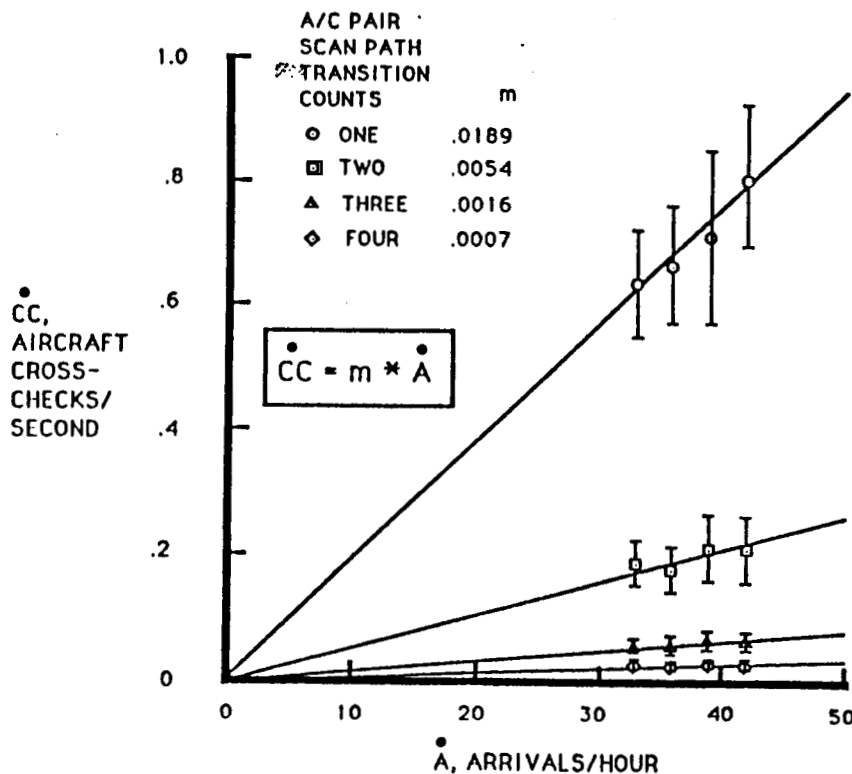
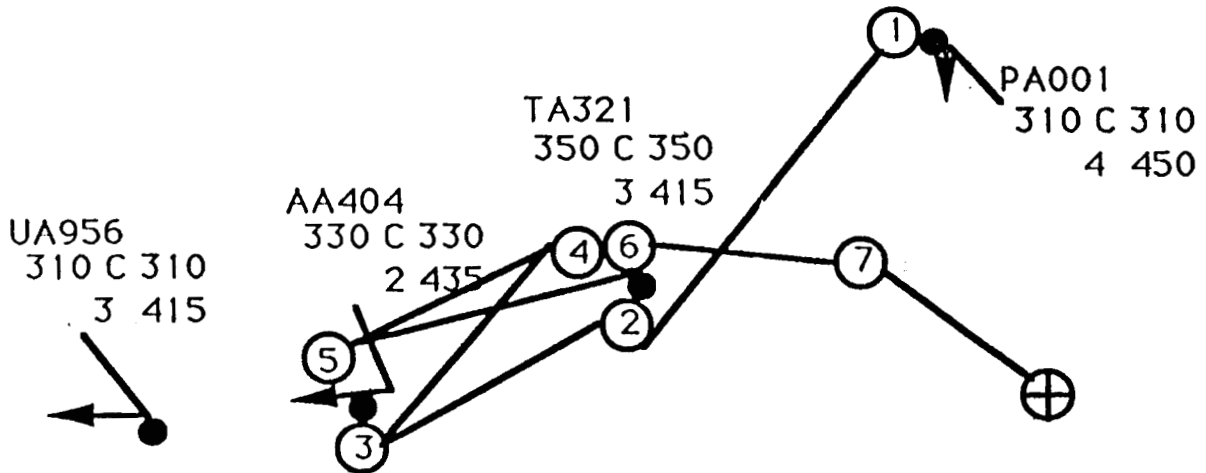


Figure 3: The Harris/Bonadies model.

# CONTROLLER MONITORS AIRCRAFT ON THE DISPLAY

## SAMPLE EYE-MOVEMENT SCAN



P  
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L

- ① Controller observes aircraft position of PA001 entering the arrival stream
- ② Controller looks at position of last AC in the arrival stream
- ③ Controller checks distance between 3rd and 2nd AC in arrival stream
- ④ ⑤ ⑥ Controller repeats distance check
- ⑦ Controller projects future aircraft position of PA001 where turn will be issued

Figure 4: The Roske-Hofstrand model.